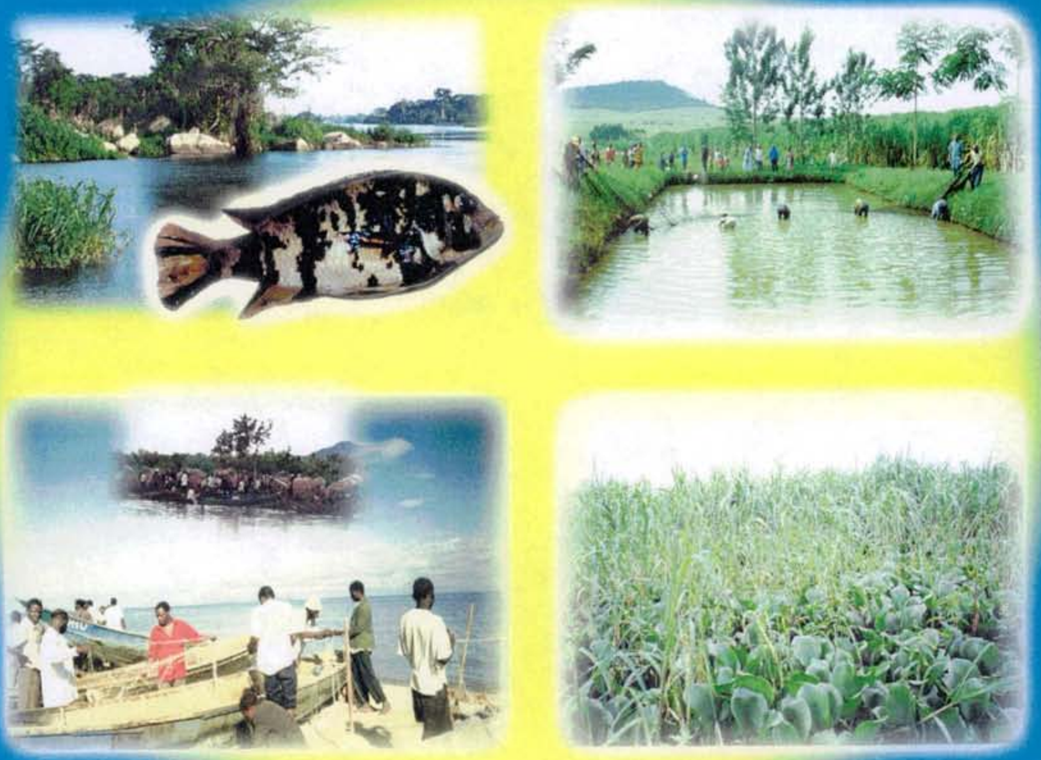
Contribution of Biological Control in Management of Water Hyacinth



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Introduction

Biological control was foreseen as the long-term strategy for controlling water hyacinth in Uganda. Two species of weevils, *Neochetina eichhorniae* and *Neochetina bruchi* were imported into Uganda from Benin (West Africa) in 1993. A total of 600 weevils of each species were imported. The weevils were tested for specificity using key agricultural crops including maize, beans and bananas and were found to be water-hyacinth specific for their food and reproduction.

Weevil rearing and field distribution

A reared weevil colony was initiated at a specifically constructed facility at Namulonge Agricultural and Animal Production Research Institute (NAARI). From the initial weevil population, rearing was later extended to onshore weevil rearing facilities (Plate 1.1) that had been built at various points along the shores of the affected lakes and rivers. On Lake Victoria, rearing facilities were constructed at Lambu in Masaka, Kasensero in Rakai, Bugoma, Kikwayo, Rutoboka and Mulabana in Kalangala, Katosi in Mukono, Masese in Jinja, Lwanika in Mayuge, Wakawaka in Bugiri, Ruizi and Kikagati in Mbarara and Majanji in Busia districts respectively. Similarly on Lake Kyoga, weevil-rearing facilities were set up in Kayeyi in Apac, Bukungu in Kamuli and Namasale in Lira districts. One rearing facility was constructed on Lake Wamala in Mubende district. As a result, an average of 3000-4000 weevils were produced and released monthly. Community participation was instrumental in weevil rearing and rapid distribution of initial weevil populations in the water bodies.

Weevils grew faster on healthy plants growing under high concentrations of nutrients and this enabled high weevil populations to build up in the lakes. The other advantage in Uganda was that the weevils grew faster, maturing within 72 and 96 days for *N. bruchi* and *N. eichhorniae* respectively compared to 96 days and 120 day reported in Australia due to optimum climatic conditions.

Monitoring Impacts of weevils on water hyacinth

The impact of weevil impact on water hyacinth has been monitored in Lake Kyoga since 1996, and in Victoria since 1998 (Fig 1.1). In Lake Kyoga, adult weevil number per plant increased from 3.4 in January 1996 to 16.8 by the late 1997. In Lake Victoria, the corresponding figures for January 1998 to late 1999 was 4.0 to 40.0 adult weevils per plant. An average weevil density per plant was maintained at 13.8 in Lake Kyoga during 1997 and 24.7 in Lake Victoria during 1999 (Tables 1.1 and 1.2). Information available in literature shows that the minimum number of adult weevils required to effectively limit growth of a water hyacinth is 10.

As the weevil population in Lake Victoria increased, most plant parameters (plant density, fresh and dry weight, height, leaf area, root length and root dry weight) declined up to 2000 (Table 1.1). A similar trend was observed in Lake Kyoga where reduction occurred in the various plant parameters during 1999 and 2000 (Table 1.2). These observations show that the weevils had a major impact on water hyacinth. The spectacular reduction in weed infestation in the water bodies was therefore caused by the of high weevil population densities.

The damage to the weed was caused by both adult and larval weevils and possible exposure to other pathogens. The adult weevils feed on the water hyacinth leaf surfaces by scraping the epidermal layer. The feeding creates numerous wounds causing desiccation to the plants. As a result the leaves curl and turn brown. The wounds also provide entry for opportunistic pathogens like fungi that weaken the water hyacinth further. Adult females lay batches of eggs on the host plant. The eggs hatch and develop into immature insects that burrow through the petioles towards the roots of the plant and cause extensive galleries in the stems. The internal damage to the plant tissues due to larval tunneling results into rotting of the petioles. Leaf damage by adults and petiole damage by larvae severely weakens the infested plants to the extent that production of new plants is retarded and plants are reduced in size. The weakened plants become water logged and either sink or remain as a disintegrating floating mass which may be carried away by water currents. Sinking of the weakened plants can be enhanced by winds and water currents as reported elsewhere in this report.

During 2000, water hyacinth resurgence was manifested by an increase in the number of plants per unit area, fresh and dry weights (Table 1.1). This resurgence was partly attributed to the crush in weevil population following massive sinking of water hyacinth in 1999, which left very few, or no weevils on the few surviving plants. However as the resurgence occurred, the weevil population started to build up and gradually depressed the weed biomass. The functioning of biological control mechanisms for water hyacinth or any other pest or predator is dependent on trends in predator-prey relationships. When there is massive biomass of water hyacinth (prey) the weevil population (predator) increases rapidly and causes a reduction in prey. Therefore, in a situation where there is weed resurgence, the weevil population builds up and suppresses the weed biomass. This cycle is repeated till an ecological balance between the weevil population and the weed is reached. This cycle is expected to re-occur whenever resurgence takes place provided there are surviving weevils in an area. In a situation where there are no surviving weevils, it will be necessary to release more weevils. Hence the need to sustain the weevil rearing facilities. Therefore, the biological control agents that were introduced in the lake have the capacity to control the weed but it may be necessary to release more weevil in situations where these have been lost due to death of the weed.

Current status of weevil population and plant morphometrics in water bodies

A survey carried on lakes Victoria, Kyoga and Albert, and River Nile in March 2002 showed variability in weevil infestation rates at different sites (Table 1.3). The average numbers of weevil ranged between 0-1.4 adults/plant in surveyed locations suggesting that the new plants may proliferate during the period of low weevil populations. The low weevil numbers were also reflected in the low level of weevil feeding scars observed on the plants. In addition, there were fewer *Neochetina bruchi* than *N. eichhorniae* and contributed about 30.2% of the total number of weevils sampled. No weevils were found in samples collected from riverine systems of Victoria Nile and River Nile. Elsewhere in lakes during this period, the number of plants per unit area was high (32-54.8 plants /m^2), although the size was greatly reduced (Table 1.4). The average plant fresh weight was low (< 500g), as was leaf length (< 50cm), leaf area (< 90cm^2), root length (< 20cm) and dry weight (<1.0

Kg/m^2). The plants at Wanseko, Goolo, Nakitokolo and Kasensero however had relatively longer roots (>30cm).

The current status of water hyacinth plants indicates that the weed is in a stage of active regrowth. This is attributed to the low weevil populations currently present in the lake as a result of the collapse of the weed biomass that was reported previously. However, during this time of weed regrowth, weevil populations are expected to build up and restore control. The control can be restored quickly when adequate numbers of both weevil species are present. Severe population reduction usually occurs in the field particularly for *N. bruchii* because it is more sensitive to deteriorating food quality of water hyacinth plants which occurs during high weevil populations. However during this time of regrowth, *N. bruchi* weevil population will build up rapidly.

Factors affecting effectiveness of weevils

The effectiveness of weevils may be affected by environmental conditions. In situations where water is highly fertile with high levels of nutrients (nitrates and phosphates), a higher number of weevils is required to bring down the plant biomass since the nutrients promote rapid growth and vigour of water hyacinth. The extra ordinary plant growth through rapid leaf production reduces the impact of the weevils. A higher number of weevils would therefore be required to suppress the plant. This is clearly manifested in Lake Victoria which has higher nutrient levels and a higher number of weevils than Kyoga (Fig. 1.1).

Hydrological conditions such as strong water currents, floods and fast flowing rivers cause sporadic removal of both weed and the associated weevils. Weed re-infestation usually occurs from plants that remain at the shoreline. Therefore periodic releases of the weevils are recommended in such situations in order to reactivate the population of weevils.

Weevils complete their life cycle by pupating in the root system of water hyacinth plants. In shallow waters near the shore, the roots of water hyacinth are embedded in mud and debris. This limits pupation and terminates the life cycle of the weevils.

When heavy weed infestation occurs in such areas, alternative methods such as manual removal may be necessary.

Advantages and Disadvantages of Biological Control

The greatest advantage in the use of biological control agents is that it is environmentally friendly. Unlike with the use of herbicides where control has to be applied carefully and selectively, biological control strategy does not have adverse effects on the environment. In addition, the set up of a US $ 3,000 biological control facility is cheap in comparison to costs associated with mechanical and manual control. Distribution of the weevils can be effective if fisherfolk are integrated in the control program as happened in Uganda. The natural enemies once established can spread to other remote areas which may not be accessible to other control options such as manual removal or use of machinery. Once biological control has been employed other integrated control methods like mechanical and manual removal can easily be carried out since the plants become lighter and reduced in size. One major disadvantage of biological control is that the biological control agents are slow in their action. Success may take place between 2- 6 years. It can therefore not be used in emergency situations to clear the weed in newly infested areas.

The Status of biological control of water hyacinth in neighbouring countries

River Kagera remains a major source of water hyacinth re-infestation of Lake Victoria because the weed has never been brought under control along the river. Regional efforts are being sought to fight the weed in the river. In respect to biological control, the Kagera Agricultural Environmental Management Program (KAEMP) constructed five weevil-rearing stations along the Kagera River, and 600,000 weevils were released during 2001. Three weevil rearing stations have been erected at ISAR/ Ruhengeri, ISAR/Gashora and Lake Ihema in Rwanda through USAID funding. Under the same support, Burundi and Rwandan nationals were trained in Uganda on techniques of weevil rearing and weevils were exported from Uganda to Rwanda to initiate rearing. To date weevils have been released in several water bodies in Rwanda. A survey carried out at Kamira bridge, Ruhengeri in February 2003 indicated low weevil populations (Table 1.5). However, there were weevil feeding marks on the plants indicating that the weevils are established. Similar weevil releases are ongoing upstream the Kagera River from Uganda's rearing station at Kasensero, and downstream from the Tanzanian rearing stations at Kyaka and Bukoba.

Despite the releases on the Kagera river system in 2001 joint surveys by nationals from Uganda, Tanzania and Rwanda indicated that weevil populations are generally low with no visible impact on the weed. The ineffectiveness of the weevils in reducing the water hyacinth infestation could be attributed to the flushing out of the plants and the weevils down stream. This may be combined with some other factors especially continuous flow of nutrient-rich water down the river which continuously replenishes nutrient supply to the plants. In order to improve the performance of the weevils in the Kagera river system, suggestions have been made to carry out weevil releases further upstream rather than downstream in fast moving parts of the river.

Weevils have also been released in the Kenyan and Tanzanian parts of Lake Victoria. In Tanzania weevils were first released in Lake Victoria in 1997 from the rearing station at Kibaha Research Institute. To date, 11 weevil-rearing stations have been constructed in the Tanzanian part of the lake; 8 are managed by the community and 3 by research institutes. From these stations several weevil releases have been made. Monitoring results indicate drastic reduction in weed infestation by over 70% and plant density reduced to an average of 28 plants/m^2 during 2000 (Mallya *et al.,* 2001). In Kenya, the first releases in Lake Victoria were made in 1997 using weevils from Kibos Research Institute. Between 1997 and 1999, several releases were made from the rearing facilities constructed at the shores of the lake. Monitoring studies carried out during 1997 to 2000 indicated reduction of plant growth parameters (fresh weight, leaf area and leaf length.

Recent survey at Karamira Bridge, Ruhengeri during February 2002 showed low weevil populations (Table 1.5). However there were weevil-feeding marks on the plants indicating that the weevils are established.

Efforts to integrate weevils and other biological control agents

There have been efforts to develop other alternative control methods to be integrated with the weevils. In East Africa, attempts are being made to develop pathogens. Pathogens, particularly those in the genera of fungi, are known to play an important role in the decline of water hyacinth populations. They attack the leaves of plants and the infected parts become weakened with time leading to senescence and death of the affected leaves.

Several potential pathogens associated with water hyacinth have been identified in East Africa. The most common ones in the region include *Alternaria eichhorniae*, *Cercospora* sp, *Acremonium zonatum, Myrothecium roridium* and *Fusarium* sp. Screen house evaluation studies show A. *eichhorniae* is the most promising and plans are underway to develop this isolate as a myco-herbicide for use against the water hyacinth in East Africa. Host specificity tests carried out on cultivated plant species in Uganda show that the pathogen has a narrow host range and is therefore regarded as safe for use in the water environment. Plans are under way to carry out similar host specificity studies in Kenya and Tanzania to confirm the safety, and to evaluate the effectiveness of different formulations.

Table 1.1. The changes in plant growth parameters with weevil density in Lake Victoria between 1998 and 2001

Parameter	Time after release			
	1998	1999	2000	2001
No of weevils /plant	13.8	24.7	6.5	8.8
Plant density (no /m^2)	66.5	54.2	46.3	52.9
Plant weight (g)	1615.1	614.0	393.0	868.2
Leaf length (cm)	68.6	51.7	52.5	47.1
Root length (cm)	46.4	39.9	35.0	40.3
Leaf area (cm^2)	91.7	69.4	83.1	71.7
Dry weight (g /m^2)	2642.3	1696.9	1076.1	924.7

Table 1.2. The changes in plant growth parameters with weevil density in Lake Kyoga between 1996 and 2001

Parameter	Time after release					
	1996	1997	1998	1999	2000	2001
No of weevils /plant	6.2	13.7	9.2	5.6	3.4	2.2
Plant density (no /m^2)	21.6	52.0	30.0	35.4	34.6	36.0
Plant weight (g)	2229.0	1180.5	1336.0	953.0	482.8	479.0
Leaf length (cm)	54.9	63.4	67.2	59.7	52.8	40.2
Root length (cm)	46.2	41.2	43.2	33.9	29.3	23.0
Leaf area (cm^2)	95.1	104.6	140.3	115.4	90.6	77.4
Dry weight (g /m^2)	2545.8	2786.5	2642.3	1696.9	1076.1	935.3

Table 1.3. Weevil population densities and species composition from different sites in Lakes Kyoga, Albert, Victoria and River Nile in March 2002.

Location	No. of weevils/plant	Percentage of weevils by species	
		N. bruchi	*N. eichhorniae*
Lake Albert			
Wanseko	0.3	12.5	87.5
Lake Kyoga			
Wigweng	0.3	0.0	100.0
Kayeyi	0.1	0.0	100.0
Kyankole	0.3	0.0	100.0
Kambatani	0.1	0.0	100.0
Iyingo	0.0	0.0	0.0
Upper Victoria Nile			
Namasagali	0.0	0.0	0.0
River Nile			
Masindi Port	0.0	0.0	0.0
Lake Victoria			
Ggolo	0.1	0.0	100.0
Nakitokolo	0.1	0.0	100.0
Gaba	0.4	50.0	50.0
River Kagera			
Kasensero	0.1	0.0	100.0

Table 1.4. Water hyacinth populations and plant morphometrics characterisation in relation to weevil abundance and damage at different sites in Lakes Kyoga, Albert, Victoria and River Nile during March 2002.

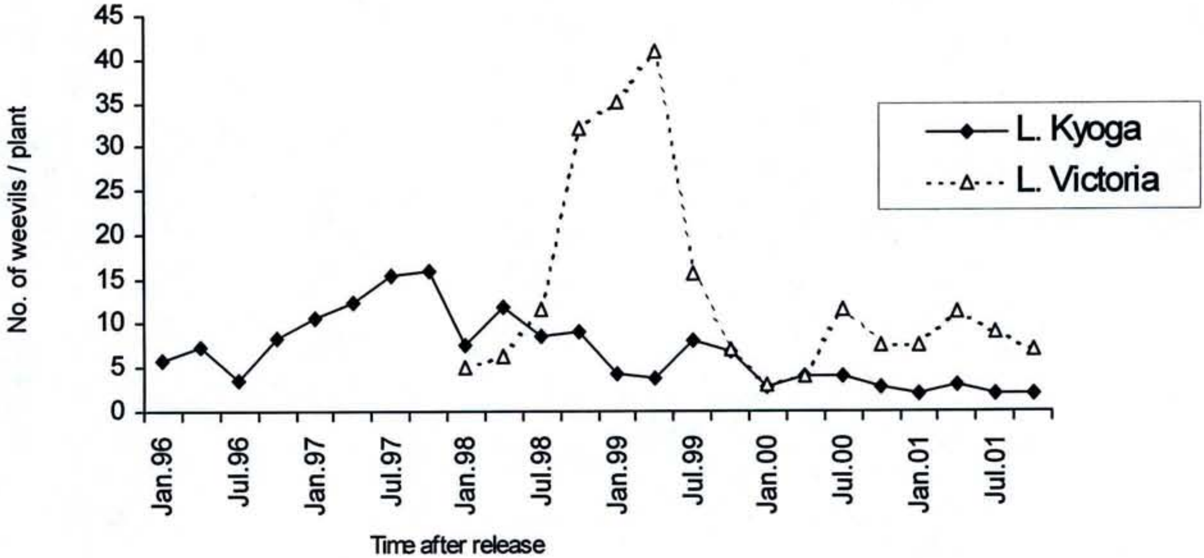
Location	No. weevils /plant	No feeding scars /plant	No Plants $/m^2$	Fresh weight (g)	Dry weight (g $/m^2$)	Leaf length (cm)	Leaf area ($cm^{2)}$	Root length (cm)
Lake Albert								
Wanseko	0.3	18.4	40.0	364.0	728.0	35.5	58.6	37.2
L. Kyoga								
Wigweng	0.3	18.5	52.0	370.6	963.6	44.2	87.5	15.8
Kayeyi	0.1	3.1	52.0	420.7	1093.8	41.2	82.0	22.3
Kyankole	0.3	14.3	48.0	248.0	595.2	30.6	69.4	14.7
Kambatane	0.1	5.3	49.3	234.7	578.5	21.1	47.5	18.5
Iyingo	0.0	0.0	54.8	254.0	696.0	21.4	40.2	14.9
Victoria Nile								
Namasagali	0.0	0.0	32.0	332.0	531.2	40.6	89.4	20.5
River Nile								
Masindi Port	0.0	0	42.0	406.7	854.1	33.2	62.0	15.8
Lake Victoria								
Goolo	0.1	4.1	45.3	475.3	1076.6	48.8	92.5	32.6
Nakitokolo	0.1	1.6	25.3	883.7	1117.9	52.0	91.5	39.1
Gaaba	0.4	23.5	36.0	533.7	960.7	50.5	117.6	19.3
R. Kagera								
Kasensero	0.1	1.1	40.0	384.3	768.7	44.8	100.5	31.9

Table 1.5. Mean number of weevils and water hyacinth parameters per ten plants sampled at Ruhengeri on the Victoria Nile.

Date: 5- 2- 02 Location: Kamira Bridge

Sample No.	*Total No. of plants/ quadrant	Total No. of rametes/quadrate	Weevil No. / 10 plants	Root length/ 10 plants	No. of scars/sample leaf	Petiole length	Leaf Area
1	14	26	0.2	33.6	4.1	28.7	81.8
2	16	27	0	37.9	0	21.7	44.9
3	9	13	0	30.3	1.3	52.9	130.5
4	4	8	0	31.8	0	48	97
5	5	10	0	34.9	0	60.2	106.8
6	6	12	0	27.8	0	40.4	107.5

* Note that these refer to TOTAL but not mean numbers per quadrat (From Ogwang, 2002)



45
40
35
30
25
20
15
10
5
0
No. of weevils / plant
L. Kyoga
L. Victoria
Jan.96
Jul.96
Jan.97
Jul.97
Jan.98
Jul.98
Jan.99
Jul.99
Jan.00
Jul.00
Jan.01
Jul.01
Time after release